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ORIGINAL ARTICLE

Eating patterns and dietary composition in relation to BMI in younger and older adults

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Objective: To compare relative associations of eating patterns and dietary composition with body mass index (BMI) in younger (aged 20–59 years, $n = 1792$) and older (aged 60–90 years, $n = 893$) participants in the Continuing Survey of Food Intakes by Individuals, collected 1994–1996.
Methods: Data from two 24-h dietary recalls from individuals reporting physiologically plausible energy intake (within $\pm 22\%$ of predicted energy requirements, based on previously published methods) were used.
Results: Mean reported energy intake was 96 and 95% of predicted energy requirements in younger and older subjects, respectively. Older subjects were less likely than younger subjects to skip a meal, but snacking was common in both age groups. Fiber density was significantly higher in the older group. A higher BMI in both age groups was associated with a higher total daily energy intake, and higher energy intakes at all eating occasions. In both age groups, eating frequency was positively associated with energy intake, and eating more than three times a day was associated with being overweight or obese. In the younger group but not the older group, a lower fiber density coupled with higher percentage of energy from fat was independently associated with having a higher BMI.
Conclusions: While no one eating occasion contributes more than any other to excess adiposity, eating more often than three times a day may play a role in overweight and obesity in both younger and older persons. A reduced satiety response to dietary fiber in addition to lower energy expenditure may potentially further contribute to weight gain in older persons.
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Keywords: energy intake; eating frequency; meal skipping; snacking; dietary fiber; dietary misreporting

Introduction

Sixty-three percent of 20- to 59-year-old and 71% of 60- to 74-year-old US adults are overweight or obese.[1] Typically, body fat doubles from young adulthood through middle age, and decreases after age 60–65 years.[2–4] Dietary factors related to overeating and obesity, particularly at different life stages, are poorly understood. Dietary fat has long been presumed to be a leading cause of weight gain.[5,6] More recently, other dietary composition factors such as fiber and energy density,[7,8] and eating patterns such as eating frequency, snacking or skipping meals have been suggested to have a potentially important influence on energy regulation.[9] However, the relative importance of these dietary factors is not known as few studies have examined eating patterns and dietary composition simultaneously in relation to body fatness.

In most studies in free-living adults of all age groups, a lower eating frequency has been associated with a higher body mass index (BMI).[10,11] Breakfast consumption has been suggested to be important for energy regulation;[12,13] however, while some studies have shown a lower percentage of total daily energy intake at breakfast associated with a higher BMI in younger[12] and older[14] persons, others have found no relationship.[13,15–17] Although snacking, usually defined as eating at occasions other than meals (e.g., breakfast, lunch or dinner), is commonly regarded as contributing to excess weight,[18,19] studies on snacking associated with BMI have also yielded mixed results.[15,20,21] One potential explanation for the equivocal findings among studies is dietary reporting bias. As suggested previously,[9,10,22] many of these studies were likely confounded by under-reporting of energy intake.[23,24] This under-reporting, primarily by overweight

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and obese persons, may be specific to energy-dense snack and dessert-type foods.[25–28] We recently reported that implausible energy intakes affect apparent eating patterns as well, being associated with lower reported meal and snack frequencies, energy densities and portions consumed.[9,10,22]

With aging comes a decline in the ability to regulate food intake. For example, older subjects failed to compensate at meals for energy preloads,[29] and did not return to starting body weight after long-term overfeeding or underfeeding as did younger subjects.[30,31] These age-related changes in energy regulation are thought to be due to altered hormonal signals, such as cholecystokinin (CCK), glucagon-like peptide 1 (GLP-1) and peptide YY (PYY), and impaired senses of taste and smell.[32–34] Potentially, changes in energy-regulating hormones during aging may result in changes in eating patterns that are associated with long-term body weight and fat changes.[21,35–37] Only a few studies, however, have specifically examined age-related changes in eating patterns.

We therefore conducted an analysis of eating patterns, dietary composition and their relative associations with BMI in younger and older adult participants in a US national survey. As it has been well established that overweight and obese individuals under-report energy intake by 30–50%,[23,24] and physiologically implausible reporters may contribute to inaccuracy in relationships between dietary factors and BMI,[22,27,38–41] we utilized our recently validated method for identifying implausible energy intake reports (i.e., those incompatible with long-term weight stability)[22] and limited our analysis to only those subjects reporting physiologically plausible energy intakes. We hypothesized that older subjects would have weaker associations of dietary factors with BMI compared to younger subjects.

Subjects and methods

Subjects

Data from the USDA Continuing Survey of Food Intake by Individuals (CSFII) collected in 1994–1996[42] were used. This survey of 16 103 non-institutionalized individuals aged 2–90 years residing in the US contains information on dietary intake (by one or two non-consecutive, multiple-pass 24-h recalls (day 1 in person; day 2 in person or by telephone)); socioeconomic, demographic and health parameters; and self-reported height and weight. From 8219 respondents aged $\geqslant$20 years, we excluded pregnant or lactating women, and individuals who were self-reported as food insecure (on welfare or 'Meals on Wheels', or did not have sufficient or suitable food), were on medically related diets, only completed one 24-h dietary recall, or did not provide height, weight or time of consumption for all eating occasions. From the remaining 6499 individuals, 41% ($n = 2685$) were determined to have reported energy intakes (rEIs) that were physiologically plausible, as described below. We divided our final sample of plausible respondents into younger (20–59 years, $n = 1792$) and older (60–90 years, $n = 893$) groups, based on evidence that on average, BMI increases with age up to about 60 years and declines thereafter.[4]

Standardization of eating occasions

Subjects self-reported the type of eating occasion at which each food was consumed: breakfast, brunch, lunch, dinner, supper or snack. However, this resulted in non-standardized coding of eating occasions and multiple same meals consumed on the same day. Therefore, as in our previous studies,[22,39] meal coding was standardized so that not more than one each of breakfast, lunch and dinner, but multiple snacks were allowed, as follows.

If two or more meals of the same eating occasion were reported within 59 min of each other, they were considered one meal and combined, using the average of the consumption times. Otherwise, the occasion with the largest energy content was coded as a meal and the others as snacks. Brunch was coded as breakfast if it occurred before 1100 hours and lunch if it occurred between 1100 and 1600 hours. In some cases, lunch was missing, but dinner and supper were both reported (some individuals named the current conventional concept of lunch in the US, that is, the midday meal, dinner). If any dinner and any supper occurred more than an hour apart, and dinner had lower energy than supper, dinner was coded as lunch and supper coded as dinner. If more than one dinner was reported, a second dinner could not be recoded to lunch unless the first dinner was already recoded to lunch, to preserve the temporal order of meals. After recoding, if breakfast, lunch or dinner were missing, the meal was considered to have been skipped. Approximately 20% of eating occasions were recoded.

Data analysis

Determination of physiologically plausible reports. Physiologically plausible reports of dietary energy intake were determined by comparing rEI with predicted energy requirements (pERs) for a low active individual (physical activity level = 1.4–1.6)[43] using previously detailed procedures.[22,41] Briefly, we calculated age group-, sex- and weight class-specific cutoffs for rEI as a percentage of pER (rEI/pER $\times$ 100%), taking into account measurement and biological intra-individual variation in rEI, and total energy expenditure (TEE),[41,43–45] as measured by doubly labeled water and error in equations for pER. When different cutoff levels were tested ($\pm$2 s.d., $\pm$1.5 s.d., $\pm$1 s.d. and 0.05 increments of $\pm$1 s.d. between $\pm$1 and $\pm$1.5 s.d. of rEI/pER $\times$ 100%), only cutoff values between $\pm$1 and $\pm$1.4 s.d. resulted in a relationship between rEI and body weight that did not differ significantly from the relationship between TEE and body weight.[22] For the present analysis, we used the $\pm$1 s.d. cutoff ($\pm$22% for these data) in order to maximize the validity of rEI. This required that an individual's rEI be within 78–122% of pER in order to be considered physiologically plausible.

Calculations. BMI (kg/m^2) was calculated using self-reported weight and height. Average dietary intakes over 2 days were used for all analyses. Energy intake and dietary composition variables, including percentage energy from fat, protein, and carbohydrate, fiber (g), fiber density (g/MJ) and energy density (kJ/g), were calculated as average daily values and by eating occasion (meals and snacks). Total daily energy density was calculated in two ways: (1) as total energy/total weight of all foods and beverages, and (2) as total energy/weight of all foods and beverages minus that of low-energy beverages, coffee and tea (pre-defined food groups in CSFII). For most analyses, nutrient intake at snacks was expressed as the average of all snacks consumed over a day, as snack frequency varied among individuals from 0 to 14/day. Eating pattern variables included total daily eating frequency and separate meal and snack frequencies, all as continuous variables. Eating frequency was also examined categorically as $\leqslant 3$, 3.5–6 and >6/day. Meal skipping (yes/no) and snacking (yes/no) were also calculated according to whether they occurred on one or both days of recorded intake.

Statistics. Descriptive demographic and dietary variables (mean ± s.e.m.) were calculated, and independent *t*-tests and χ^2-tests were used to compare characteristics between younger and older subjects. Energy and dietary composition variables across eating occasions were compared within- and between-age groups by analysis of variance (ANOVA), with Bonferroni adjustments for multiple comparisons. ANOVA was also used to compare energy intake distribution across eating occasions among normal weight (BMI <25 kg/m^2), overweight (BMI 25–29.9 kg/m^2) and obese (BMI $\geqslant 30$ kg/m^2) subjects within each age group.

Multiple regression analysis was conducted to determine associations between energy intake and BMI in each age group. Age group differences in these associations were tested for significance as explained above. Multiple regression analysis was also used to determine the relative associations of dietary composition and eating pattern variables with BMI in each age group. Macronutrients, fiber density, energy density, eating frequency (continuous and categorical), meal and snack frequency, meal skipping and snacking were considered as independent variables. Selected interactions between variables were also examined, including fiber density by the percentage of energy from fat (based on our previous analysis[38]), and eating frequency by dietary composition variables. To determine whether dietary composition at specific eating occasions was associated with BMI, additional models with dietary composition at each eating occasion entered simultaneously were also tested. To determine whether meal skipping was associated with increased snack frequency, models with meal skipping (yes/no) were tested with all three meals considered simultaneously. Finally, the association of eating frequency with energy intake was also tested.

All regression models were controlled for age, sex, education level (high school or less vs beyond high school), current smoking (yes/no), self-reported chronic disease (yes/no for at least one of the following: diabetes, hypertension, heart disease, cancer, hypercholesterolemia and/or stroke), ethnicity (white vs non-white), annual household income (0–130, 131–350 and >350% of poverty threshold), urbanicity (urban, suburban, rural), geographic region (northeast, midwest, south, west) and television viewing (h/day) (as a proxy for inactivity). In separate analyses, models were additionally controlled for low-energy containing beverages, coffee and tea. This was carried out because eating occasions could conceivably consist of only non-energy or low-energy containing beverages, and because our preliminary analyses indicated positive associations between these variables and BMI, thereby potentially confounding the association between eating frequency and BMI. Regression analyses were also conducted on the subset of individuals without self-reported chronic disease ($n = 1417$ younger and 312 older subjects), with qualitatively similar results (data not shown). Regression analysis of eating frequency associated with energy intake was additionally controlled for height because there is a strong association between height and energy requirements independent of weight or BMI.[43]

The unweighted mean variation of rEI/pER $\times$ 100% (sample-specific) and weighted partial R^2's from regression analyses were calculated using SAS v.8.2 (Cary, NC, USA). *T*-tests, R^2 and χ^2-tests, and linear regression analyses were performed using SUDAAN v.8 (Research Triangle Park, NC, USA) and weighted for sampling design, with alpha set at 0.05. SUDAAN was used to incorporate the CSFII sample design (stratified, multistage area probability sample) for variance estimation. Failure to account for sampling design is known to underestimate standard errors of parameters, hence increasing the risk of rejecting true null hypotheses. A *P*-value of $\leqslant 0.05$ was considered significant.

Results

Demographic and dietary characteristics of younger and older persons

Demographic characteristics are shown in Table 1. Mean BMI and prevalence of underweight or overweight and obesity did not differ between age groups. However, older subjects were less educated and less likely to smoke, and were more likely to be Caucasian, have a major disease and spend more time watching TV.

Dietary energy and composition are shown in Table 2. In both younger and older subjects, energy intake reporting plausibility (i.e., energy intake as a percentage of energy requirements) was similar and very high on average. Older subjects, however, reported a lower absolute energy intake than younger subjects, reflecting the lower energy require-

Table 1 Characteristics of younger and older adult participants in the Continuing Survey of Food Intakes by Individuals 1994–1996 reporting physiologically plausible energy intakes[a]

	Younger	*Older*
n	1792	893
% Male	57	55
Age (years)	38.5±0.4	71.0±0.4*
BMI (kg/m^2)	25.2±0.1	25.4±0.2
Underweight (% wt./BMI ⩽18.5 kg/m^2)	3.0	2.6
Overweight/obese (% wt./BMI ⩾25 kg/m^2)	47	50
TV viewing (h/day)	2.3±0.1	3.1±0.1*
Current smoker (%)	24	13*
Education, high school or less (%)	40	58*
Urban (%)	30	35
Caucasian (%)	84	91*
With disease (%)[b]	22	65*
Below 130% poverty level (%)	8	9

Abbreviation: BMI = body mass index. [a]Values are mean±s.e.m., except where percentages are shown. [b]Self-reported condition of at least one of the following: diabetes, high blood pressure, heart disease, cancer, high blood cholesterol and stroke. *Significantly different from younger group ($P<0.05$).

ments of older persons.[43] Dietary composition differences between age groups were significant but tended to be very small on average. The exception was fiber density, which was much higher in older subjects compared to younger subjects.

Table 2 also shows the eating patterns of the two age groups. Older subjects consumed more meals and fewer snacks per day than did younger subjects (Table 2), so that no significant difference in total eating frequency existed between the two age groups. Meal skipping was common, with 44% of all subjects having skipped at least one meal on at least one of the two dietary recall days. Older subjects tended to skip fewer meals than younger subjects, particularly breakfast. In addition, both age groups skipped lunch more often than they skipped breakfast. Snacking was also very common in both groups, with the majority of subjects (>92%) having snacked on at least one recall day.

Meal skipping was associated with a higher snacking frequency in both age groups. In the younger group, skipping breakfast ($\beta=0.20\pm0.09$, $P=0.03$) and dinner ($\beta=0.32\pm0.11$, $P<0.02$), and in the older group, skipping breakfast ($\beta=0.73\pm0.19$, $P<0.001$) and lunch ($\beta=0.33\pm0.11$, $P<0.01$) were independently associated with increased snack frequency after controlling for socioeconomic and lifestyle factors. Because these associations implied that snacks were replacing meals (or *vice versa*), and because the designation of meals and snacks can be somewhat arbitrary,[18,46] we also calculated the distribution of eating frequency categories among younger and older subjects. The percentage of subjects who ate ⩽3, 3.5–6 and >6 times a day, respectively, did not differ significantly between age groups, being 15, 75 and 10% in the younger group, and 14, 77 and 9% in the older group.

Energy and macronutrient intake by eating occasion are shown in Table 3. Energy intake at breakfast did not differ significantly between age groups, but the older group

Table 2 Eating patterns and dietary composition in younger and older adult participants in the CSFII 1994–1996 reporting physiologically plausible energy intakes[a]

	Younger	*Older*
n	1792	893
Eating patterns		
Eating frequency (no./day)	4.6±0.1	4.5±0.1
Meals (no./day)	2.7±0.0	2.8±0.0*
Snacks (no./day)	2.1±0.1	1.9±0.1*
Skipped meal[b]		
Breakfast (%)	22	5*
Lunch (%)	28	27
Dinner (%)	10	8*
At least one of any meal (%)	48	37*
Snacked (%)[b]	94	92
Dietary composition		
Energy intake (MJ/day)	10.1±0.1	8.4±0.1*
Predicted energy requirement (MJ/day)	10.4±0.0	9.1±0.0*
Energy intake/predicted energy Requirement × 100 (%)	95.8±0.4	94.5±0.4*
Carbohydrate (% energy)	49.7±0.3	51.2±0.4*
Protein (% energy)	15.2±0.1	15.7±0.1*
Fat (% energy)	34.0±0.3	33.1±0.3*
Energy density (kJ/g)	4.1±0.0	3.9±0.0*
Fiber (g/day)	17.8±0.3	18.8±0.4*
Fiber density (g/MJ)	1.8±0.0	2.3±0.0*

Abbreviation: CSFII = Continuing Survey of Food Intakes by Individuals. [a]Values are means±s.e.m., except where proportions are shown. [b]Defined as skipping at least one meal or snacking on either one or both dietary recall days. *Significantly different from younger group ($P<0.05$).

consumed less energy than the younger group during lunch, dinner and snacks. Both age groups consumed the highest proportion of their total energy intake at dinner and, while the younger group's lowest proportion of their total energy intake was consumed at breakfast, the older group's lowest proportion of their total energy intake was consumed in snacks. The macronutrient and fiber composition of meals and snacks also differed. In general, in both age groups, lunch and dinner were highest in percent energy from protein and fat and energy density, and dinner was highest in total fiber (g). However, while dinner was also highest in fiber density (g/MJ) for younger subjects, breakfast was highest in fiber density for older subjects. Snacks were the least fiber-dense eating occasions in both age groups.

Relationships of total energy, meal and snack energy and composition with BMI

Figure 1 shows energy intake at each eating occasion by weight class. In the younger age group, energy intake at all eating occasions was lower in normal weight compared to overweight and obese subjects. In older subjects, energy intake at breakfast was significantly lower in normal weight than overweight (but not obese) subjects. Also, energy intake in snacks was significantly lower in older normal weight and overweight subjects compared to older obese subjects. In both age groups, differences between weight classes no

Table 3 Energy intake and macronutrient composition by eating occasion in younger and older adult participants in the CSFII 1994–1996 reporting physiologically plausible energy intakes

	Breakfast	*Lunch*	*Dinner*	*Snacks*
Energy intake (kJ/day)				
Younger ($n=1792$)	1577 ± 21^{a}	2640 ± 51^{b}	3826 ± 37^{c}	1962 ± 50^{d}
Older ($n=893$)	1694 ± 41^{a}	$2004\pm45^{b*}$	$3205\pm51^{c*}$	$1487\pm53^{a*}$
Energy intake (% total)				
Younger	15.9 ± 0.2^{a}	26.3 ± 0.5^{b}	38.3 ± 0.3^{c}	19.5 ± 0.4^{d}
Older	$20.4\pm0.5^{a*}$	$24.8\pm0.5^{b*}$	38.1 ± 0.5^{c}	$17.4\pm0.6^{d*}$
Carbohydrate (% energy)				
Younger	59.1 ± 0.7^{a}	45.4 ± 0.4^{b}	42.8 ± 0.4^{c}	58.8 ± 0.7^{a}
Older	$65.0\pm0.8^{a*}$	45.3 ± 0.6^{b}	43.7 ± 0.5^{c}	57.6 ± 0.7^{d}
Protein (% energy)				
Younger	11.8 ± 0.2^{a}	16.1 ± 0.1^{b}	18.8 ± 0.2^{c}	7.5 ± 0.2^{d}
Older	$13.1\pm0.2^{a*}$	$16.8\pm0.3^{b*}$	18.7 ± 0.2^{b}	8.1 ± 0.2^{c}
Fat (% energy)				
Younger	25.8 ± 0.4^{a}	35.1 ± 0.3^{b}	36.0 ± 0.4^{b}	24.6 ± 0.6^{a}
Older	$24.0\pm0.7^{a*}$	$32.2\pm0.4^{b*}$	36.5 ± 0.4^{c}	24.6 ± 0.6^{d}
Energy density (kJ/g)				
Younger	3.6 ± 0.1^{a}	4.9 ± 0.1^{b}	5.0 ± 0.1^{b}	3.9 ± 0.1^{c}
Older	$3.1\pm0.1^{a*}$	$4.3\pm0.1^{b*}$	4.9 ± 0.1^{c}	$4.3\pm0.1^{bc*}$
Fiber (g)				
Younger	2.9 ± 0.1^{a}	4.7 ± 0.1^{b}	7.4 ± 0.2^{c}	2.9 ± 0.1^{a}
Older	$4.4\pm0.2^{a*}$	4.5 ± 0.2^{a}	7.2 ± 0.2^{b}	2.7 ± 0.1^{c}
Fiber density (g/MJ)				
Younger	1.8 ± 0.1^{a}	1.8 ± 0.0^{a}	2.0 ± 0.0^{b}	1.5 ± 0.0^{c}
Older	$2.6\pm0.1^{a*}$	$2.2\pm0.1^{bc*}$	$2.3\pm0.1^{b*}$	$2.0\pm0.1^{c*}$

Abbreviation: CSFII = Continuing Survey of Food Intakes by Individuals. Values are means ± s.e.m. Values in same row with different superscript letters differ significantly (adjusted $P<0.0125$ (Bonferroni correction)). *Significantly different from younger group ($P<0.05$).

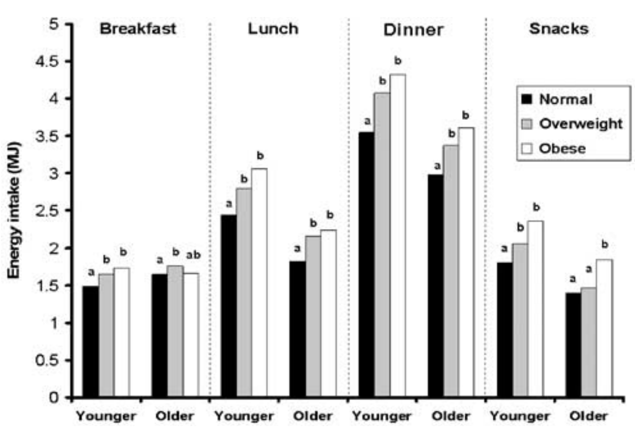

Figure 1 Adjusted mean energy intakes at meals and aggregate snacks in normal weight (BMI $<25\,kg/m^2$), overweight (BMI 25–29.9 kg/m^2) and obese (BMI $\geqslant 30\,kg/m^2$) younger (20–59 years) and older (60–90 years) subjects participating in the CSFII and reporting physiologically plausible energy intakes (see text for explanation). Bars with the same letter within an age group are not significantly different. $n=1792$ younger, 893 older.

longer existed when energy intake was expressed as the percentage of total daily energy intake (data not shown).

Total energy intake, controlled for socioeconomic and lifestyle parameters, was positively associated with BMI in both age groups (younger: $\beta=1.23\pm0.07$, $P<0.001$; older: $\beta=1.21\pm0.11$, $P<0.001$), and when data from both age groups were pooled for analysis, these associations did not differ significantly. Energy intake accounted for 18% of the total variance in BMI in the younger group and 12% in the older group. When energy intakes at all meals and snacks were entered simultaneously in a model predicting BMI, all were independently and positively associated with BMI in both the younger and older groups ($P<0.0001$ for all). When associations of dietary composition (fiber density, percent energy from fat, their interaction and energy density) at breakfast, lunch, dinner and snacks were entered in a model simultaneously, only percent energy from fat at lunch was positively associated with BMI in the younger group. In the older group, none of the variables were associated.

Relationships of eating patterns and total dietary composition with BMI

Regression models for the relative associations of eating patterns and dietary composition with BMI are shown in Table 4. In the younger group, the best-fit model (Younger Model 1) consisted of fiber density, a fiber density by percent energy from fat interaction and eating frequency. Fiber

Table 4 Models predicting BMI from dietary factors and eating patterns in younger and older adults reporting plausible energy intakes[1]

	β-coeff.	s.e.	Partial R^2	P-value
Younger (n = 1792)				
Model 1				
Constant	22.01	1.38		<0.001
Fiber density (g/MJ)	−1.74	0.50	0.0063	0.001
Fat (% energy)	0.00	0.04	0.0206	0.942
Fiber density (g/MJ) × fat (% energy)	0.04	0.02	0.0021	0.016
Eating frequency (no./day)	0.30	0.08	0.0043	<0.001
Model R^2			0.1769	<0.001
Model 2				
Constant	21.89	1.44		<0.001
Fiber density (g/MJ)	−1.74	0.50	0.0063	0.001
Fat (% energy)	0.00	0.04	0.0206	0.961
Fiber density (g/MJ) × fat (% energy)	0.04	0.02	0.0020	0.016
Snack frequency (no./day)	0.28	0.07	0.0038	<0.001
Meal frequency (no./day)	0.35	0.21	0.0007	0.104
Model R^2			0.1763	<0.001
Model 3				
Constant	23.20	1.39		<0.001
Fiber density (g/MJ)	−1.75	0.50	0.0063	0.001
Fat (% energy)	−0.00	0.04	0.0206	0.970
Fiber density (g/MJ) × fat (% energy)	0.04	0.02	0.0021	0.016
Eating frequency (no./day)				
⩽3 (reference)	—	—	—	—
3.5–6	0.37	0.28	0.0005	0.197
>6	1.28	0.44	0.0027	0.006
Model R^2			0.1747	<0.001
Older (n = 893)				
Model 1				
Constant	29.02	3.37		<0.001
Fiber density (g/MJ)	−0.46	0.73	0.0010	0.532
Fat (% energy)	0.02	0.07	0.0103	0.725
Fiber density (g/MJ) × fat (% energy)	0.01	0.02	0.0003	0.643
Eating frequency (no./day)				
⩽3 (reference)	—	—	—	—
3.5–6	0.87	0.37	0.0037	0.022
>6	2.32	0.75	0.0089	0.004
Model R^2			0.1346	<0.001

Abbreviation: BMI = body mass index. All models are controlled for age, sex, race, TV viewing, current smoking, education, US region, urbanicity, income and self-reported chronic disease (data not shown).

density was inversely associated with BMI, and examination of the fiber density by percent energy from fat interaction indicated that a low fiber density coupled with a high percent energy from fat was positively associated with BMI. The main effect of percent energy from fat was not significant. In this model, dietary composition accounted for 2.9% of the between-subject variation in BMI, whereas eating frequency, which was positively associated with BMI, accounted for 0.4% of the between-subject variation in BMI. We found similar associations when meal and snack frequencies were entered (Younger Model 2) instead of eating frequency, but in this case only snack frequency was significantly associated with BMI (although meal frequency approached significance). A third model (Younger Model 3), with eating frequency as a categorical variable, is shown for comparison with the model obtained in older group (Older Model 1). In the older group, only when eating frequency was coded categorically was it significantly associated with BMI. Furthermore, none of the dietary composition variables that were significantly associated with BMI in the younger group were significant in the older group. In the older group, eating frequency accounted for approximately 1.3% of the between-subject variance in BMI, whereas in the younger group it accounted for approximately 0.3% (as a categorical variable). Other dietary composition and eating pattern variables, including snacking (yes/no) and meal skipping (yes/no), did not predict BMI in either group. In each of the models in the younger and older groups, all of the variables that were significant remained so even after controlling for intake (g) of low-energy beverages, coffee and tea. Furthermore, low-energy beverages themselves were independently associated with BMI in the younger group, and both low-energy beverages and coffee and tea were independently associated with BMI in the older group ($\beta = 0.0009$–0.0025; $P < 0.0001$–0.03).

Mean BMI and energy intake in relation to eating frequency categories are shown in Figure 2, adjusted for socioeconomic and lifestyle parameters as well as the other dietary variables shown in Table 4. In general, both BMI and energy intake increased with increasing eating frequency in both age groups. In the younger group, BMI was significantly higher among subjects eating >6 times a day compared to those eating $\leqslant 6$ times a day. In the older group, BMI was significantly higher among subjects eating >3 times a day compared to those eating $\leqslant 3$ times a day. In both age groups, energy intake increased significantly among subjects in each increasing category of eating frequency.

Discussion

This is the first study to simultaneously examine eating patterns and dietary composition in relation to BMI in younger and older adults. We found that a higher total energy intake, and energy intake at all meals and snacks, rather than any particular eating occasion, was associated with a higher BMI in both age groups. In addition, a higher BMI in both age groups was associated with a higher eating frequency. Also, despite their more fiber-rich diets than younger subjects, BMI in older subjects was not associated with fiber density or the fiber density by percent energy from fat interaction as it was in younger subjects. Along with previous studies, our findings provide further evidence for increased energy dysregulation with aging, and suggest that older adults may have a somewhat reduced sensitivity to dietary factors that typically help regulate appetite in younger adults.

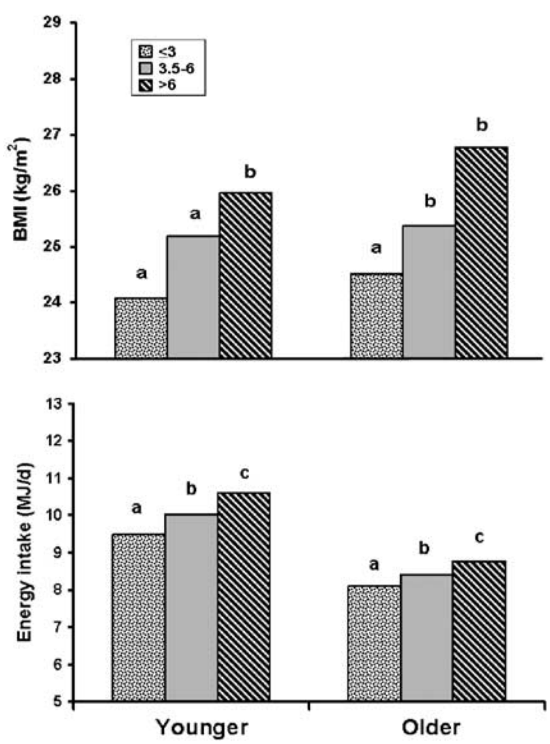

Figure 2 Adjusted mean BMI and energy intake in relation to daily eating frequency (number per day) in younger (20–59 years) and older (60–90 years) subjects participating in the CSFII and reporting physiologically plausible energy intakes (see text for explanation). Eating frequency was categorized as $\leqslant 3$, 3.5–6 and >6/day. The 0.5 increments in eating occasions is due to the averaging of 2 days of intake. Values are adjusted for sex, age, education level, current smoking, self-reported chronic disease, ethnicity, household income, urbanicity, geographic region and television viewing. Bars with the same letter within an age group are not significantly different. $n = 1792$ younger, 893 older.

Age-related differences in physiology may help explain the small variations between younger and older adults in energy compensation and the associations of dietary factors with BMI observed in this study. Gastric emptying is delayed after meals in older subjects, increasing satiation.[47] Older individuals also have a decreased olfactory sense and increased taste threshold[48,49] and may experience less intense hunger signals;[29,31,47] therefore, they may be less sensitive to stimulation by the presence of food than younger persons. However, differences with age in hormonal mechanisms that regulate sensitivity to dietary factors are uncertain. Stimulation of satiety hormones such as CCK, GLP-1 and PYY in response to dietary factors may be altered as people age.[49,50] Some studies have reported that CCK increases more markedly in response to fat in older persons,[51] but a heightened sensitivity to CCK with advanced age has not been clearly demonstrated.[50] Likewise, basal concentrations of GLP-1 and PYY are comparable and increase similarly after fat infusion in younger and older subjects.[51] Behavioral factors may also contribute to different eating patterns and an apparent reduced sensitivity to satiety cues with age. For example, older people may be less attentive to hunger or satiety cues than younger persons and instead follow certain eating patterns out of habit, concern for health or according to a schedule.[52,53] The lower activity of older persons may also contribute to a reduced appetite.[54] Thus, the extent to which hormonal, physical and behavioral changes influence appetite in older people is still unclear.

We found that in younger adults, both dietary composition and eating frequency were independently associated with BMI. A higher fiber density was associated with a lower BMI. In addition, while percent energy from fat was not by itself associated with BMI, a high percent energy from fat coupled with a diet low in fiber density was positively associated with BMI. These findings are consistent with intervention studies showing an average of -1.9 kg weight loss over 3.8 months with the addition of 1–25 g/day of fiber to *ad libitum* diets,[55] and greater weight loss with both a decrease in fat intake and an increase in fiber intake compared to either one alone.[56] We also found that dietary composition may be more strongly related to BMI than eating frequency in younger adults, as dietary composition accounted for approximately six times the variance in BMI than did eating frequency (2.9 vs 0.4%). In older adults, however, eating frequency (categorically) was the only dietary factor that we examined that was associated with BMI. However, the relatively smaller sample size of the older group may have precluded finding dietary associations. Our eating frequency categorical models showed that in older adults, eating frequency accounted for about 1.3% of the variation in BMI, approximately four times that of younger adults. Both younger and older adults consumed more energy and had correspondingly higher BMIs with each increasing category of eating frequency. However, eating frequency may be a more critical factor in weight control in older adults, perhaps due to their lower energy requirements,[43] whereas it may be only one of several factors in younger adults. These differences need to be substantiated in future studies.

The positive association of eating frequency with BMI that we observed in this study is in contrast to previous reports of either no relationship or an inverse relationship between eating frequency and BMI or percent body fat in free-living persons.[10,11,57–63] Also contrary to previous reports showing breakfast skipping, reduced energy intake at breakfast and/or increased energy intake later in the day being associated with a higher BMI or energy intake,[11,12,14,64] we found no such relationships. Instead, total energy intake, or energy at *all* meals and snacks rather than any particular eating occasion, was associated with a higher BMI in both age groups. Some reasons that our findings conflict with those of previous studies are that we took into account all eating occasions at one time in our statistical models, and we excluded subjects with physiologically implausible reports of energy intake from our analysis.[22]

It has been demonstrated unequivocally that overweight and obese subjects are more likely to provide physiologically implausible reports of energy intake than normal weight subjects,[23,24,41,65,66] typically under-reporting energy intake by 30–50%. Older persons may also under-report energy intake.[67–69] In our previous analyses, we showed that including only plausible reports resulted in stronger relationships of both eating patterns and dietary composition with BMI in subjects across all age groups.[22,38,39] Our studies also provided strong evidence that when implausible reporting occurs, whole eating occasions are omitted, and reported portion sizes and energy density of both meals and snacks are lower in the total sample compared to the sample limited to plausible reporters.[22,39] Thus, it is not surprising that we observed different relationships of both eating patterns and dietary composition with BMI in our study than have been previously reported, and we recommend that future epidemiological studies on dietary associations with BMI also identify and screen out implausible energy intake reports.

We observed that, in both younger and older persons, a higher BMI was associated with higher total daily energy intakes, and in a separate model, energy intake at all meals and snacks. We also found that increased eating frequency was associated with increases in energy intake and BMI. Skipping meals was not associated with BMI. Skipping meals was, however, associated with an increase in snacking frequency, which suggests that either snacks were replacing meals, or that, as suggested by others,[18,46] the designation of eating occasions as a meal or a snack is somewhat arbitrary. We considered the potential different influences of meal vs snack frequency on energy regulation, and found that a higher snack frequency was associated with a higher BMI in younger persons, whereas meal frequency was only marginally associated. These differential associations with BMI may be explained by the lower range of meal frequencies (0–3/day) vs snack frequencies (0–14/day) in our sample. Taken together, these data suggest that an individuals' energy intake may be achieved by several avenues, either a combination of a low eating frequency and higher portion consumed, or a higher eating frequency with a lower portion consumed, in any combination of meals and snacks. Our study provides strong evidence, however, that free-living subjects who eat more often, regardless of whether the eating occasions are designated as meals or snacks, have higher energy intakes. Therefore, higher eating frequencies may be associated with higher total daily energy intakes and hence over time, weight gain, unless cognitive efforts to reduce portion size are practiced consistently.

Interestingly, older subjects skipped meals less often than younger subjects, and meal frequency was slightly higher and snacking frequency slightly lower. This supports the notion that older persons may eat somewhat more regularly or have a tendency to eat according to a schedule, whereas younger persons may eat more haphazardly and perhaps schedule eating around other activities. In particular, breakfast skipping was much less common in the older group: only 5% of older subjects vs 22% of younger subjects skipped breakfast on either one or both recall days. The most frequently skipped meal by both age groups was lunch, with ~27% of subjects skipping lunch on one or both days. Snacking was quite common among both older and younger persons, with over 92% of subjects snacking on at least one of the recall days, as has been observed by others.[70,71] However, as noted previously, neither meal skipping nor snacking *per se*, nor energy intake at any one eating occasion, was associated with BMI; rather, total eating frequency was the eating pattern that had the strongest positive association with energy intake and BMI in both age groups.

The major strength of this study is that when we excluded implausible reporters of energy intake, we obtained 95% reporting accuracy in a large national data set. However, there were some limitations. Our previous analysis in younger subjects suggests that there may be differences between men and women in dietary composition relationships with BMI.[38] Nonetheless, in our preliminary analyses in older subjects, only minor differences between men and women were present. Therefore to maximize statistical power, particularly in the older group, which had a smaller sample size than the younger group, we elected to present our analysis with men and women combined, controlling for sex. Weight and height were self-reported. Our method of recoding meals may have misclassified meals as snacks or *vice versa*; however, as discussed in the methods section, it was necessary to implement a coding scheme that would allow us to interpret the eating pattern data, as self-reported eating occasions were originally not standardized across individuals. Regarding physical activity, we did not have a good measure but relied on TV viewing hours per day as a proxy of inactivity level. Finally, while the CSFII 1994–1996 may be considered somewhat 'out of date', it is a very rich data set with 2 days of dietary intake per participant, compared with more recent surveys that contain only 1 day of dietary intake per person or rely upon the less precise food frequency questionnaires to determine intake. It would be very useful, however, to analyze additional data sets with the same questions in mind as the present study had, so that consistency among findings from different surveys can be assessed.

Conclusions

Older people may be less sensitive to satiety cues than younger people, despite having somewhat more regular eating patterns and choosing a more fiber-dense diet. Our data suggest that a reduction in eating frequency may be one way to reduce excess energy intake in overweight and obese persons of all ages, while in younger persons additional advice on increasing dietary fiber and reducing dietary fat is warranted.

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